

Patent Claims

1) Device having at least one moveable component, in particular compressors or valves for an apparatus serving for the production of polarized gases, in particular  $^3\text{He}$ -gas, having furthermore

1.1 a housing,

1.2 a first space contained in that housing which is in some conducting connection with the outside.

1.3 A second space within that housing which is in some conducting connection with a closed system comprising the polarized gas, said device characterized in that

1.4 in between said first and said second space is placed at least one more intermediate space such that any penetration of contaminants into said second space which is in connection with said closed space is being prohibited as much as possible.

2) Device according to claim 1,

characterized in that said intermediate space comprises a pumping connection.

3) Device according to claim 1 or 2,

characterized in that said moveable components within said housing are pistons of compressors or tappet rods of pistons or of valves.

4) Device according to one of the claims 1,2,3,

characterized in that said device serves as an outlet valve such that the valve is tightened via an adjunct tappet which is coupled with a certain free play of movement to a tappet according to claim 3 such that

4.1 in case of said tappet being placed in an intermediate position, said adjunct tappet will tighten said valve only by an overpressure on the side of the outlet of said valve.

4.2 In case of said tappet being moved into its forward position, said adjunct tappet will close said valve by force, independently of the pressure conditions.

4.3 In case of said tappet being moved into the rear position, said adjunct tappet will open said valve by force, independently of pressure conditions.

5) Device according to claim 4,

characterized in that said intermediate space has a sufficient extension such that the stroke of said piston or of said tappet of said device is always shorter than the extension of said intermediate space in the direction of movement.

6) Element according to one of the claims 1 - 5,  
characterized in that said device comprises several of said moveable components, placed next to each other in such a way that said intermediate spaces which belong to said moveable components are connected to each other in a conductive manner.

7) Element according to one of the claims 1 - 6,  
characterized in that said intermediate space is sealed by gaskets fixed in notches around the said piston or the said tappet or the surrounding cylinder.

8) Element according to one of the claims 1 - 7,  
characterized in that all components of said elements which are in direct contact with the polarized  $^3\text{He}$  comprise nonmagnetic or weakly magnetic materials having low outgassing rates.

9) Element according to one of the claims 1 - 8,  
characterized in that the components which are moved at/ or exposed to mechanical wear and tear comprise little outgassing titanium or bronze.

10) Element according to one of the claims 1 - 9,  
characterized in that said element is a compressor, designed in a way that the dead volume in the cylinder head is minimized when the piston is in the forward position.

11) Element according to one of the claims 1 - 10,  
characterized in that said piston of said compressor or said tappet or said valve are driven by a hydraulic gear.

12) Element according to one of the claims 1 - 11,  
characterized in that said hydraulic gear of said piston comprises two pressurized chambers inside of said piston.

13) Element according to one of the claims 1 - 12,  
characterized in that the gear of said compressor comprises a fast running crankshaft with  
conrod.

14) Device for the production of nuclear spin polarized fluids, in particular  ${}^3\text{He}$  gas including:

#### 14.1 An assembly for optical pumping in a low pressure plasma.

14.2 a compressor assembly for compressing the polarized medium and

### 14.3 a storage volume.

characterized in that

14.4 said compressor assembly comprises at least one component according to one of the claims

1-13

15) Device according to claim 14,

characterized in that the valves of said device for producing polarized media comprises components according to one of the claims 1 -13

16) Device according to claim 15,

characterized in that several valves of said device for producing polarized media are gathered into valve blocs.

17) Device according to claim 16,

characterized in that said valve blocs comprise an intermediate vacuum common for a number of valves and that the intermediate vacua are connected to each other via bores.

18) Device according to claim 17,

characterized in that one or several of said valve blocs comprise the inlet valve from said optical pumping assembly to said compressor assembly and / or the outlet valve from said compressor assembly into said storage volume.

19) Device according to claim 17 or 18.

characterized in that one or several of said valve blocks comprise

the valves for evacuating said optical pumping assembly and / or for controlling the gas flows.

and the pressure monitors.

20) Device according to one of the claims 15 - 19,  
characterized in that the pipeline system of the device for gas transport and evacuation  
comprises little outgassing aluminum tubes, tightend by metal rings.

21) Device according to one the claims 15 - 20,  
characterized in that said device comprises ahead or after said optical pumping assembly  
(seen in the direction of flow) selectively absorbing getters.

22) Device according to claim 21,  
characterized in that said getters comprise nonferromagnetic getter substances.

23) Device according to claim 21 or 22,  
characterized in that said getters are evaporation getters.

24) Device according to claim 22 or 23,  
characterized in that said getter substances comprise little relaxing titanium.

25) Device according to claim 23 or 24,  
characterized in fact that said getter substances comprise Bismuth.

26) Device according to one of the claims 23 - 25,  
characterized in that said optical pumping assembly comprises itself one or several of said  
evaporation getters.

27) Device according to claim 26,  
characterized in that said evaporation getter is part of said optical pumping assembly and is  
operated as a cathode in the plasma region of said optical pumping assembly in order to bind  
other gases fast and selectively.

28) Device according to one of the claims 23 - 27,  
characterized in that said evaporation getters comprise cooling set-ups.

29) Device according to one of the claims 15 - 28,

characterized in that said device is designed such that the dead volume within

- said cylinder head,
- said outlet valve of said compressor assembly to said storage volume and
- said pipelines to said storage volume

are being minimized in order to enable a fast and almost complete gas transport from said compressor assembly to said storage volume.

30) Device according to claim 29,

characterized in that the stroke volume of said compressor is designed in such a way that the fraction of the gas which remains in the dead volume and relaxes therein is being minimized.

31) Device according to one of the claims 15 - 30,

characterized in that said compressor assembly comprises a compressor cylinder and that the ratio of the circumference of the said compressor cylinder to the stroke volume of said compressor is smaller than  $1/(30\text{cm}^2)$ , preferably smaller than  $1/(100\text{cm}^2)$ , and most preferably smaller than  $1/(300\text{ cm}^2)$ .

32) Device according to one of the claims 15 - 31,

characterized in that said optical pumping set-up comprises at least one long cell containing the optically pumped low pressure plasma.

33) Device according to claim 32,

characterized in that said cell comprises mirrors which serve to double the absorption path length of the pumping light within said cell, thereby conserving the degree of circular polarization.

34) Device according to claim 33,

characterized in that said mirrors are designed as being transparent for certain spectral lines of  $^3\text{He}$ .

35) Device according to one of the claims 15 -34,

characterized in that the light source of said optical pumping assembly features a spectral distribution which is adapted to the Doppler-width of the absorption line of the noble gas.

36) Device according to claim 35,  
characterized in that said light source is a laser light source and that for a given laser power  
the cross section of the laser beam is designed in such a manner that the resulting light  
intensity will not surpass the saturation value of maximum optical pumping rate.

37) Device according to one of the claims 32 - 36,  
characterized in that said optical pumping assembly comprises imaging optical elements being  
arranged outside said optical pumping cells in order to focus the beam from the light source  
such that the cross section of said beam remains everywhere smaller than the cross section of  
the cell in order to prevent for instance depolarizing reflection from the cell walls.

38) Device according to one of the claims 32 - 37,  
characterized in that at least the entrance and the outlet windows of said low pressure cells are  
made of glass of optical quality.

39) Device according to claim 38,  
characterized in that an element for determining the degree of circular polarization of light is  
provided and that said degree of circular polarization is determined by taking the difference of  
a maximum and a minimum measured voltage value and dividing it by their sum, these  
measurements being performed by passing the light first through a  $\lambda / 4$  retardation plate  
followed by a liquid crystal element and finally a linear polarizer before it generates in a  
photo detector one or the other of said voltage values depending on a positive or negative  
voltage signal applied to the liquid crystal element which reacts on said positive or negative  
voltage signal by forming a bi-refringent optical delay plate featuring delays of either an even  
or an odd multiple of half of the wave length  $\lambda / 2$  or vice versa.

40) Device according to claim 35,  
characterized in that said element for determining the degree of circular polarization is being  
used to determine the degree of nuclear polarization of said noble gas plasma.

41) Device according to one of the claims 14 - 40,  
characterized in that said optical pumping set-up comprises at least one high frequency driven  
electrode powering the plasma.

42) Device according to one of the claims 14 - 41,  
characterized in that said device comprises at least one pumping assembly to which said  
intermediate vacua of said elements with moveable components are being connected.

43) Device according to claim 42,  
characterized in that said device comprises a purification assembly for purifying the gas  
pumped out of said intermediate vacua with the possibility to recycle that purified gas within  
said device.

44) Procedure for producing nuclear spin polarized gases, in particular  $^3\text{He}$  gas comprising  
the following steps:

44.1 Optical pumping in a low pressure plasma and  
44.2 followed by mechanical compression of the gas and  
44.3 transport into a storage volume,  
characterized in that the method of fractional pumping is being applied in the compression  
process.

45) Procedures according claim 44,  
characterized in that said fractional pumping is performed by an element according to one of  
the claims 1 -12.

46) Procedure according to one of the claims 44 - 45,  
characterized in that the production of the nuclear spin polarized gases is performed by help  
of a device according to one of the claims 14 - 41.

47) Procedure according to one of the claims 44 - 46,  
characterized in that said intermediate vacua are pumped actively.

48) Procedure according to one of the claims 44 - 47,  
characterized in that the gas will be purified from contaminants by getter devices before and/  
or during optical pumping and / or compression.

49) Procedure according to claim 48,

characterized in that said getter devices are being cooled.

50) Procedure according to claim 49,

characterized in that said getter devices are cooled down to the temperature of liquid nitrogen.

51) Procedure according to one of the claims 44 - 50

characterized in that the compression up to a pressure smaller than 10 bar is performed with one and the same compressor device.

52) Procedure according to one of the claims 44 - 50

characterized in that the noble gas which is being pumped out of the actively pumped vacua is being purified and recycled to the device for producing polarized noble gases.